Project ID: EEMS011

U.S. DEPARTMENT OF ENERGY

SMARTMOBILITY

Systems and Modeling for Accelerated Research in Transportation

Integrated Mesoscale Urban Systems Modeling with Behavior, Energy, Autonomy, and Mobility (BEAM) to Explore Shared and Automated Vehicles and their Impacts on Energy and Mobility

Colin Sheppard, LBNL
2019 VTO Annual Merit Review
June 11, 2019

Argonne NATIONAL LABORATORY | INL Idaho National Laboratory | BERKELEY LAB | OAK RIDGE National Laboratory | NREL NATIONAL RENEWABLE ENERGY LABORATORY

Overview

Timeline

- Start date: 10/2016
- End date: 09/2019
- Percent complete: 90%

Budget

- Total funding: $2.1M
  - –DOE share: 100%
- FY 2017: $0.5M
- FY 2018: $0.5M
- FY 2019: $1.1M

Barriers

- Limited understanding of system-impacts of mobility mega-trends
- Scalable modeling of future transportation system difficult
- Models need appropriate representation of behavior

Partners

- Project Lead: LBNL
- Partners: LBNL, NREL, ORNL, INL, ANL

Objectives & Relevance

Challenge

- Transportation systems becoming more dynamic, connected, and complex
- Travelers are faced with more modal options and situational awareness than ever before

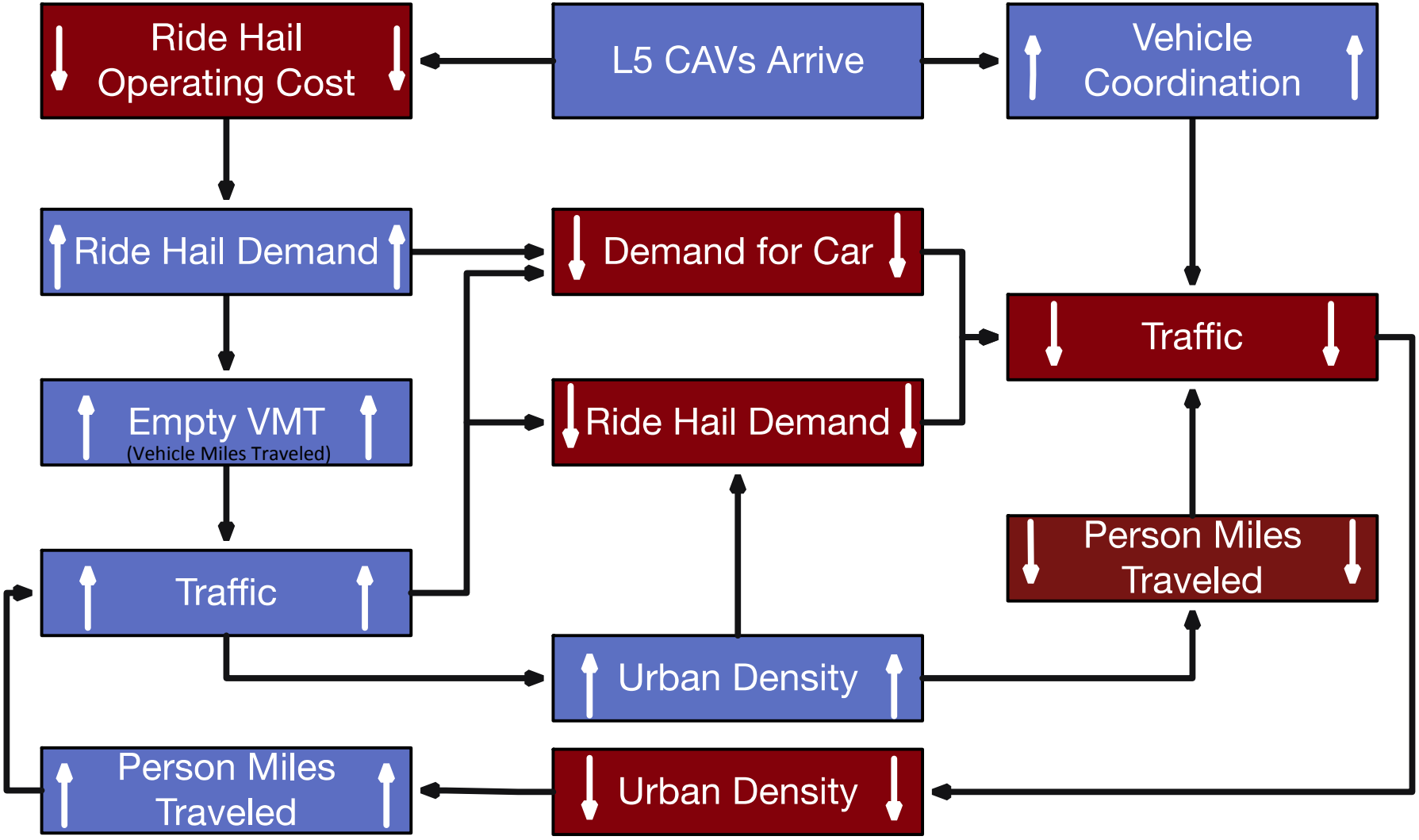
Goals

- Assess energy and mobility impacts of vehicle automation, sharing economy, and vehicle electrification
- Capture feedbacks in travel demand models as transportation system becomes more dynamic and demand responsive
- Supports EEMs/VTO Goal: Linking long-term travel behavior (e.g. land use) with short/medium term system changes from emerging mobility technologies and services

Milestones

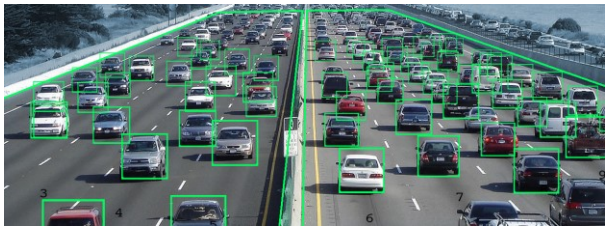
Date	Milestone	Status
September 2018	Report on calibration results, medium-term traveler behavior study, and ride hail vs. transit analysis.	Complete
March 2019	Model additions including household connected automated vehicle (CAV) ownership and scheduling, ride hail pooling, human driven ride hail, coordinated adaptive cruise control (CACC) impact on traffic flow, model integrations with several other models in SMART consortium. Preliminary Implementation of Workflow Taskforce model scenarios.	Complete
June 2019	Completion of Workflow scenario analysis	Complete
September 2019	Final results included in SMART Capstone Reports.	On track

Challenge: Complex Feedbacks



Approach: Systems Modeling

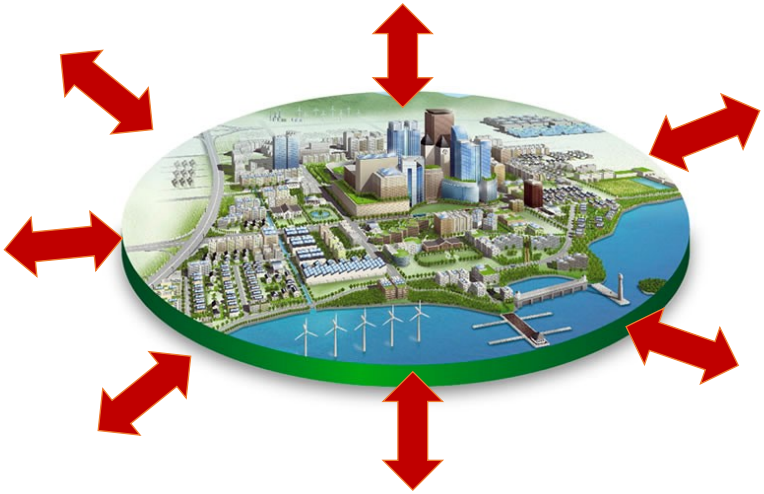
New Forms of Mobility



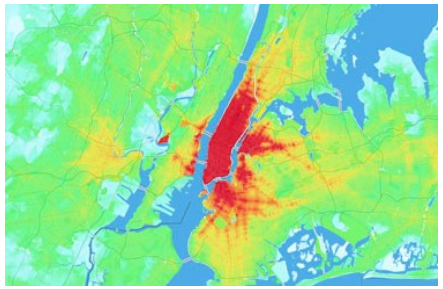
Enhanced Traffic Flow

Vehicle Ownership /
Vehicle Energy Performance

Traveler Behavior



Charging Siting & Operations



Advanced Accessibility Analysis

Land Use Change

Approach: Systems Modeling

- New modeling capabilities to enable large-scale, agent-based simulations of multimodal urban transportation systems
- Design an extensible simulation framework that can readily accommodate new mobility modes and new insights into or models of traveler behavior
- Validate the model against existing data sources
- Conduct scenario analyses of mobility mega-trends

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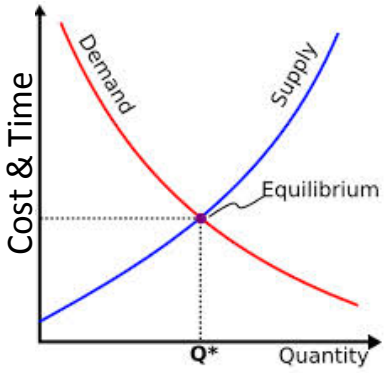
Technical Accomplishments Summary

	Sub-Task
1	SMART Scenario Coordination
2	Behavioral Refinements
3	Ride Hail Pooling
4	Human Driven Ride Hail
5	CAVs / CACC
6	FASTSim / Route-E Integration
7	Vehicle Sharing
8	MEP Integration
9	UrbanSim Integration

BEAM

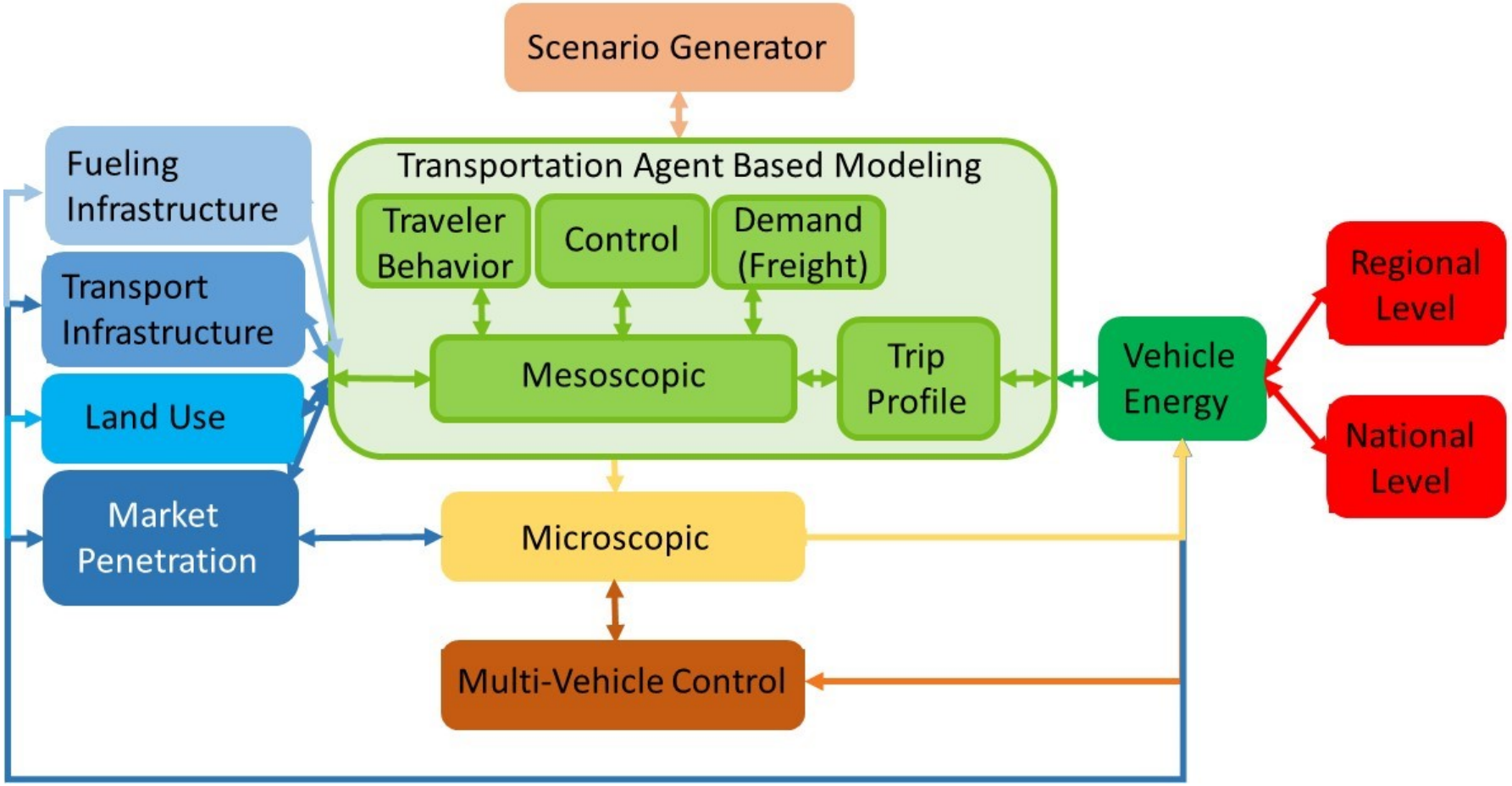
BEAM simulates Resource Markets

- Since AMR ’18, we added new resource markets to BEAM:
  - Road Capacity
  - Vehicle Capacity
  - Parking/Refueling Access
  - TNC Availability (enhanced previous solution)

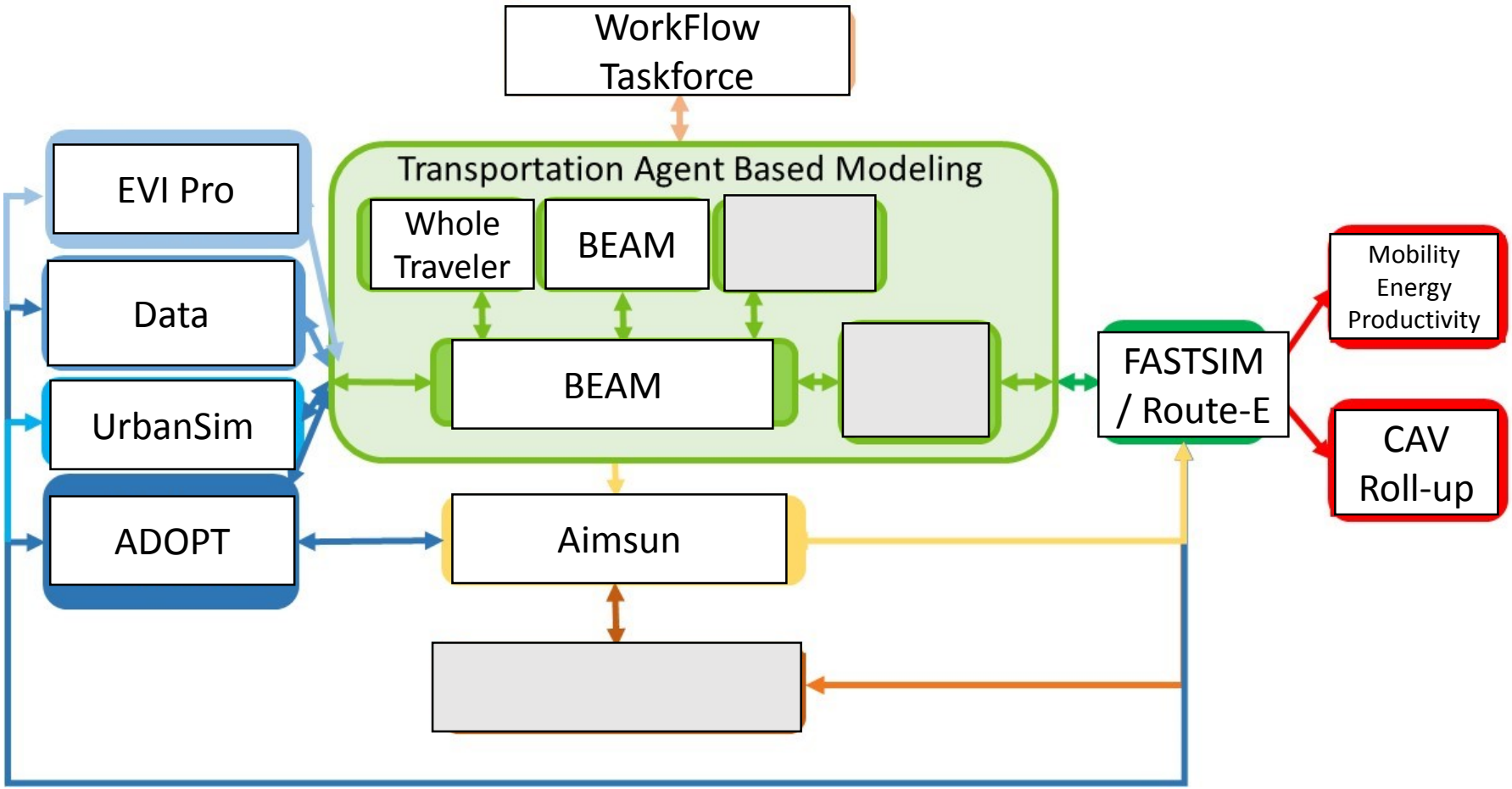


- These markets are composed of:
- Supply:
  - Driving
  - Transit
  - Intermodal (drive to transit)
  - Walk / Bike
  - Ride Hail (centrally managed)
  - Parking
  - Vehicle Sharing
- Demand (governed by behaviors):
  - Mode Choice
    - Price & Time Sensitive
  - Route Choice
    - Multimodal
  - Rerouting
  - Parking Choice

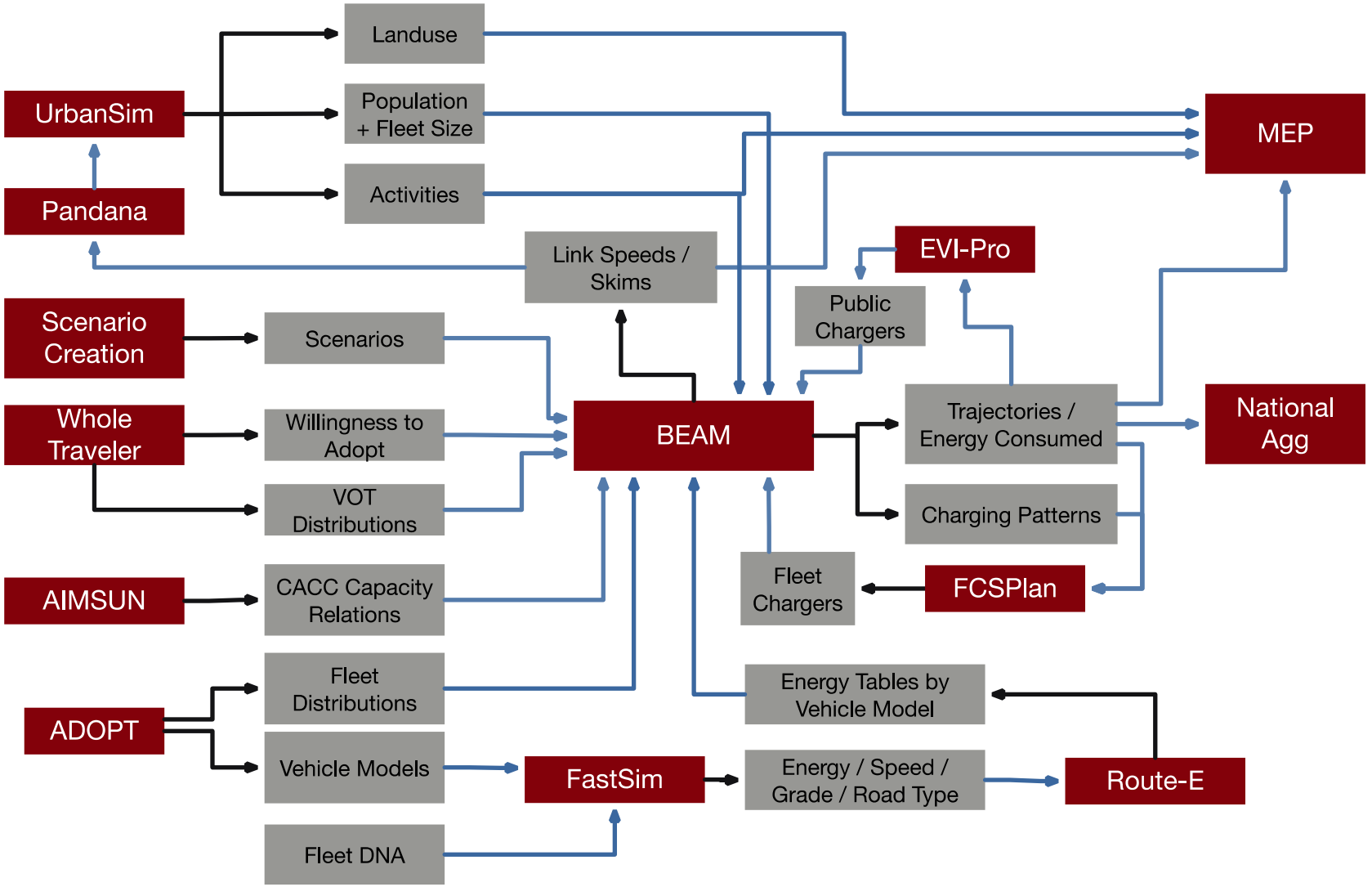
SMART Scenario Coordination



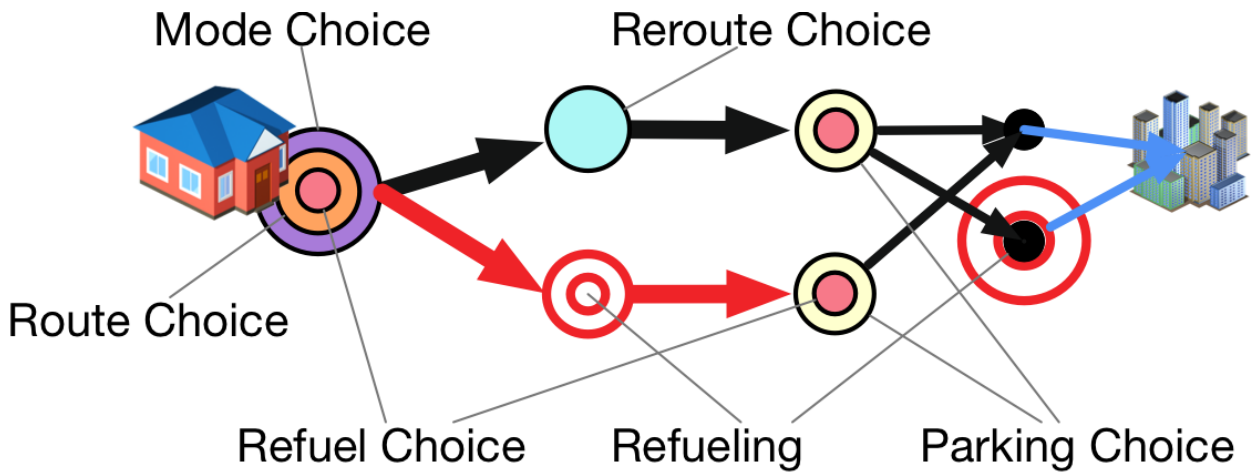
SMART Scenario Coordination



SMART Scenario Coordination



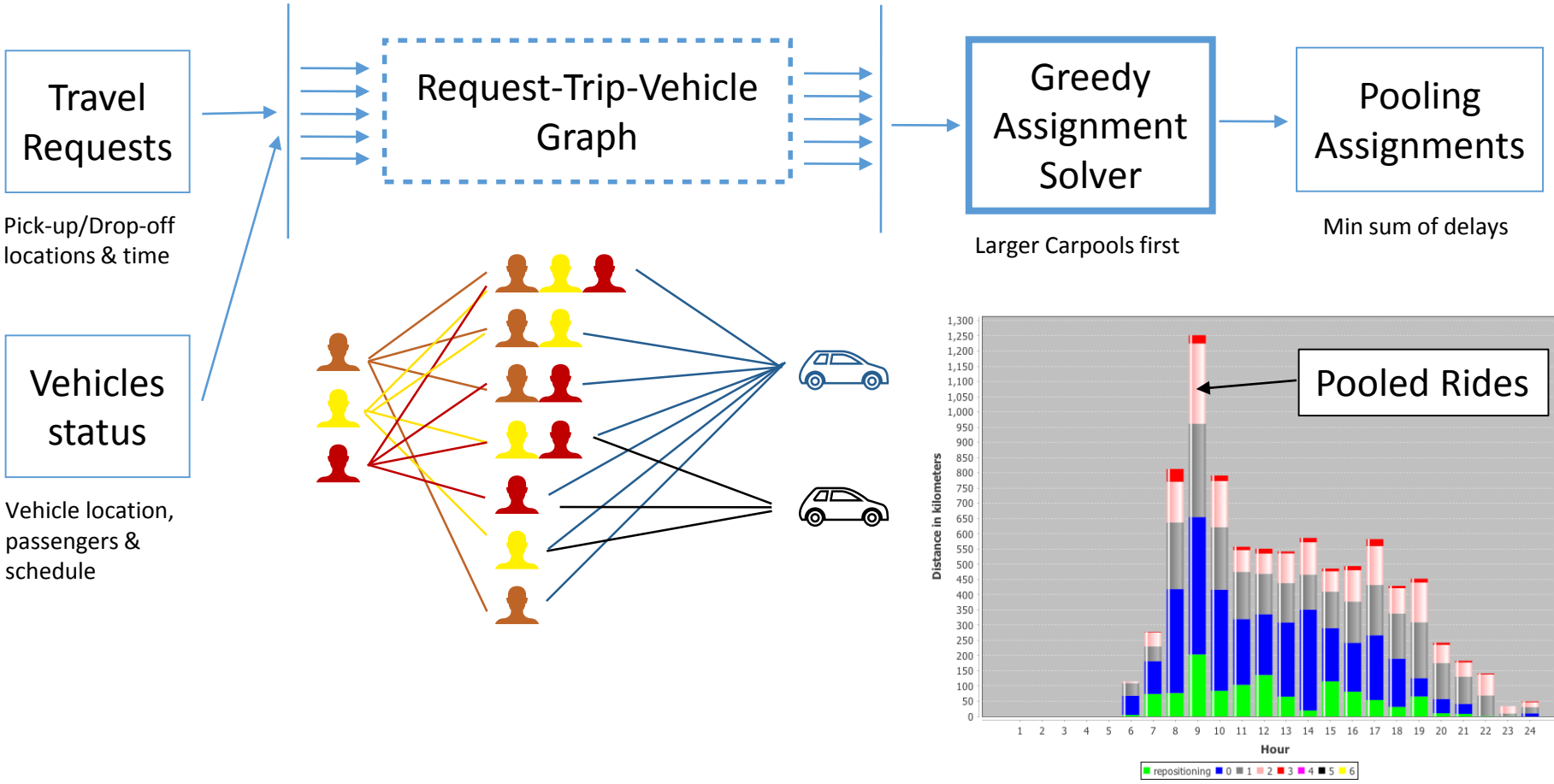
Behavioral Refinements



- Value of travel time is highly context dependent:
  - Driving:
    - Congested / uncongested
    - Time critical (commuted to work) versus non-critical
    - In a self-driving vs human-driven
  - Ride hailing:
    - With driver / without driver
    - Pooled / Solo
  - By Mode
    - transit vs walk vs bike

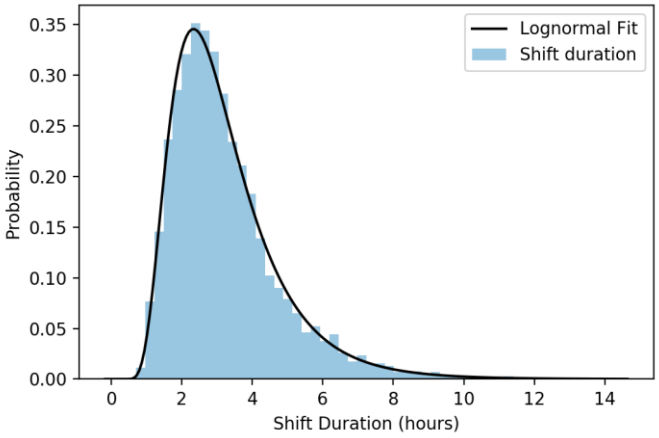
Ride Hail Pooling

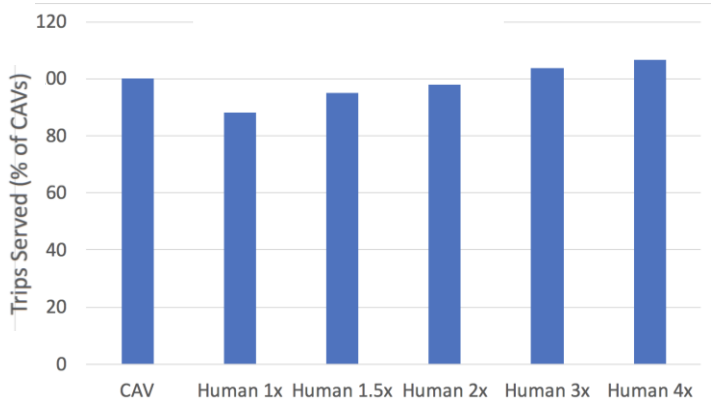
- Asynchronous Pooling Assignment based on Alonso-Mora algorithm

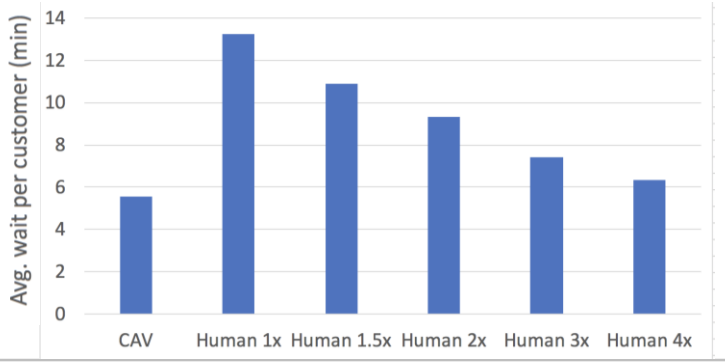


Human Driven Ride Hail

- Ride hail drivers work according to shifts
- Initial location and fleet distributions customizable
- Temporal distribution based on trip demands







Ride Hail Transit Routing

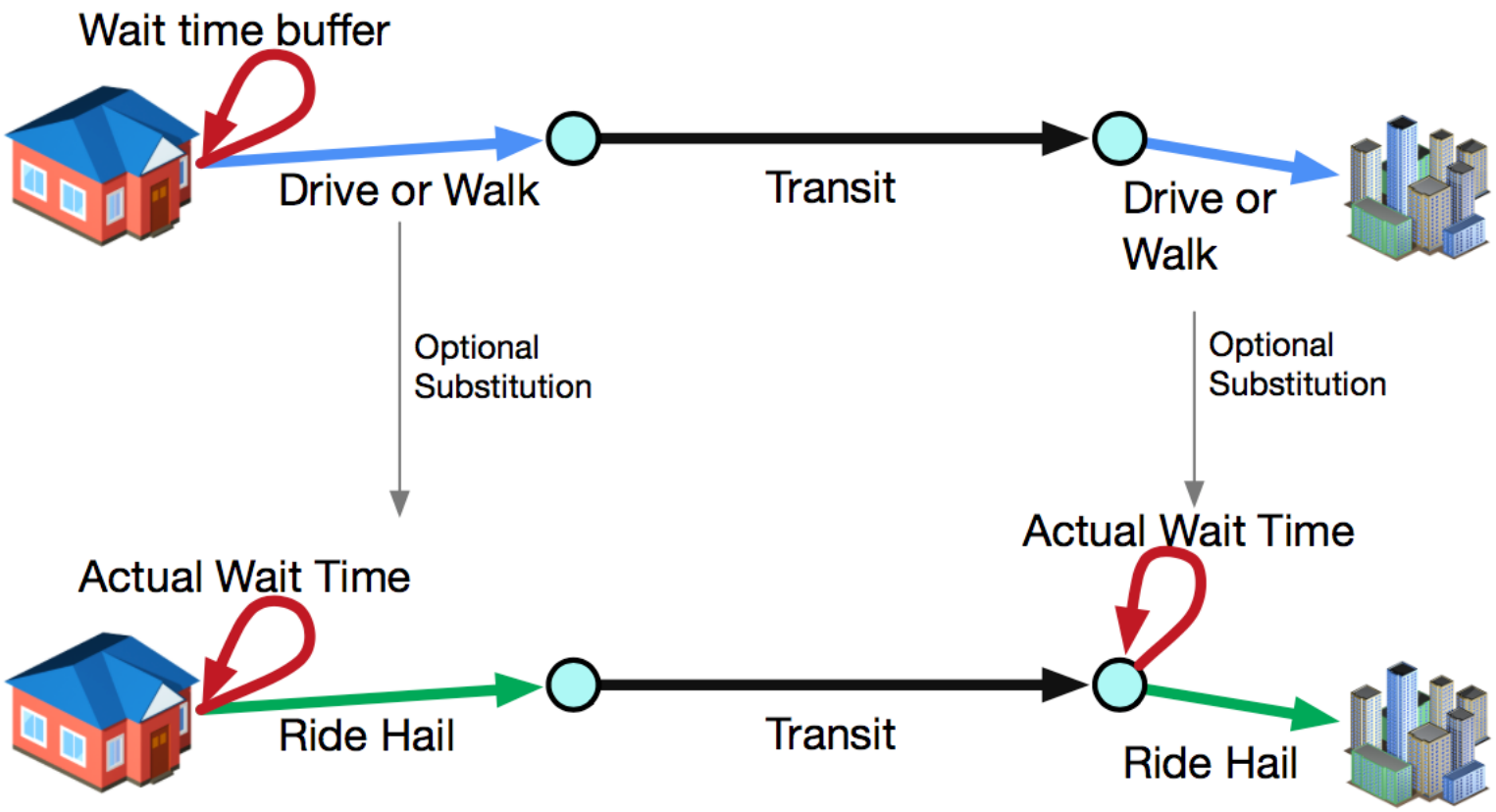


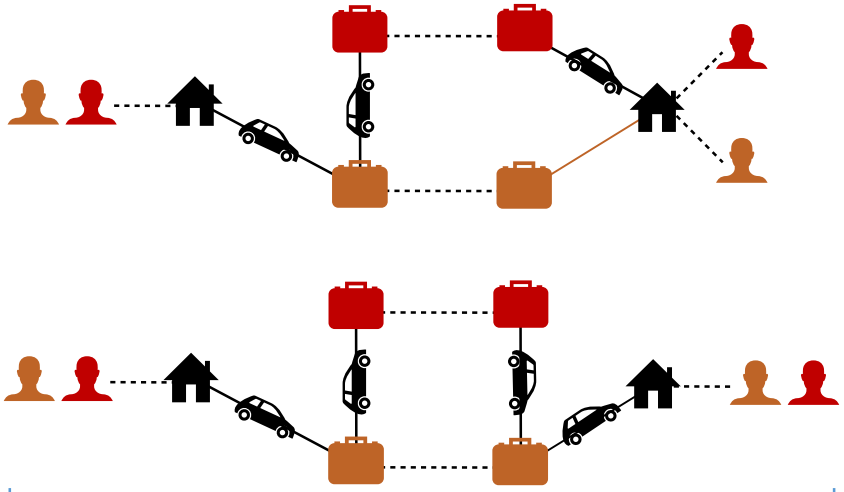
Figure 1: How a ride hail to/from transit trip is constructed in BEAM.

Household CAV Ownership and Scheduling

Household Travel Requests

Household Trips & Chain-based Tours

Household Fleet of CAVs



Whole Day Combinatorial Assignment

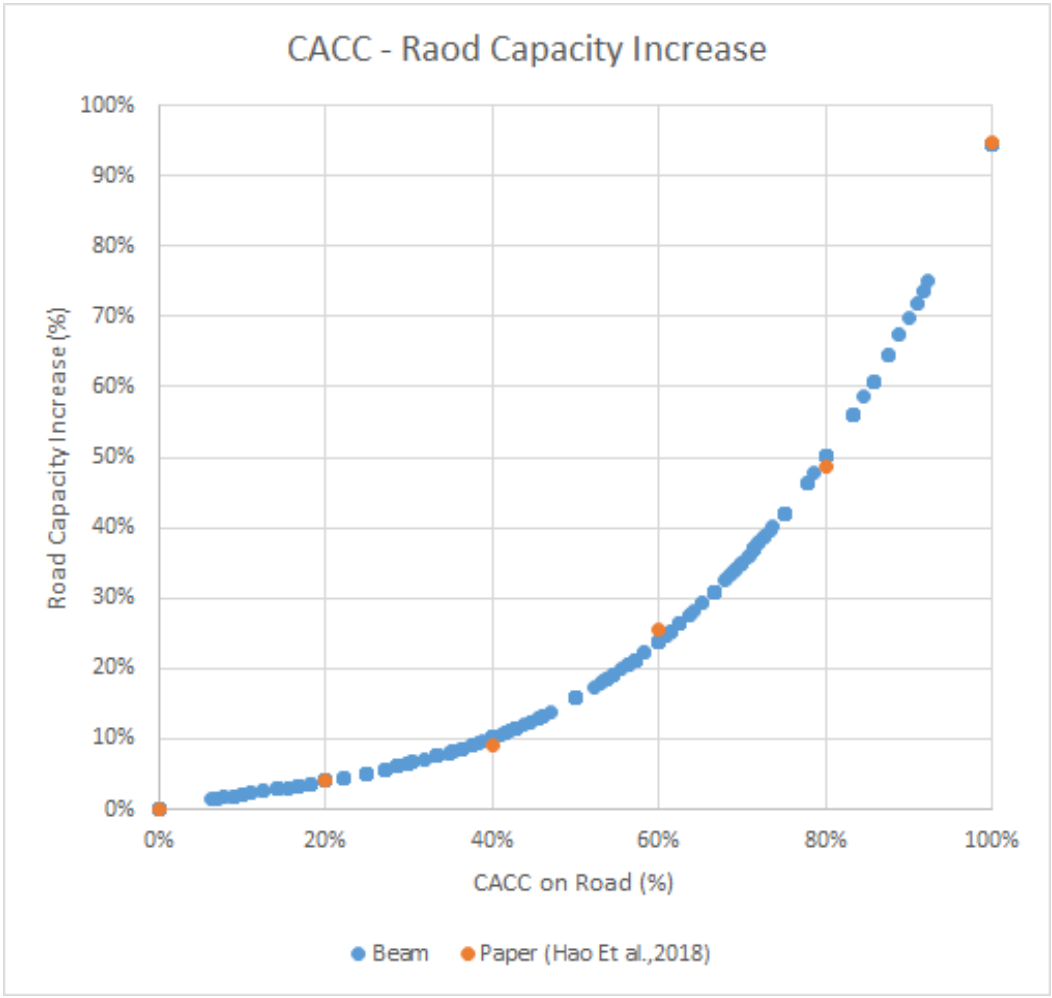
(First to ask is the first to be served)

Scoring + CAV Assignments

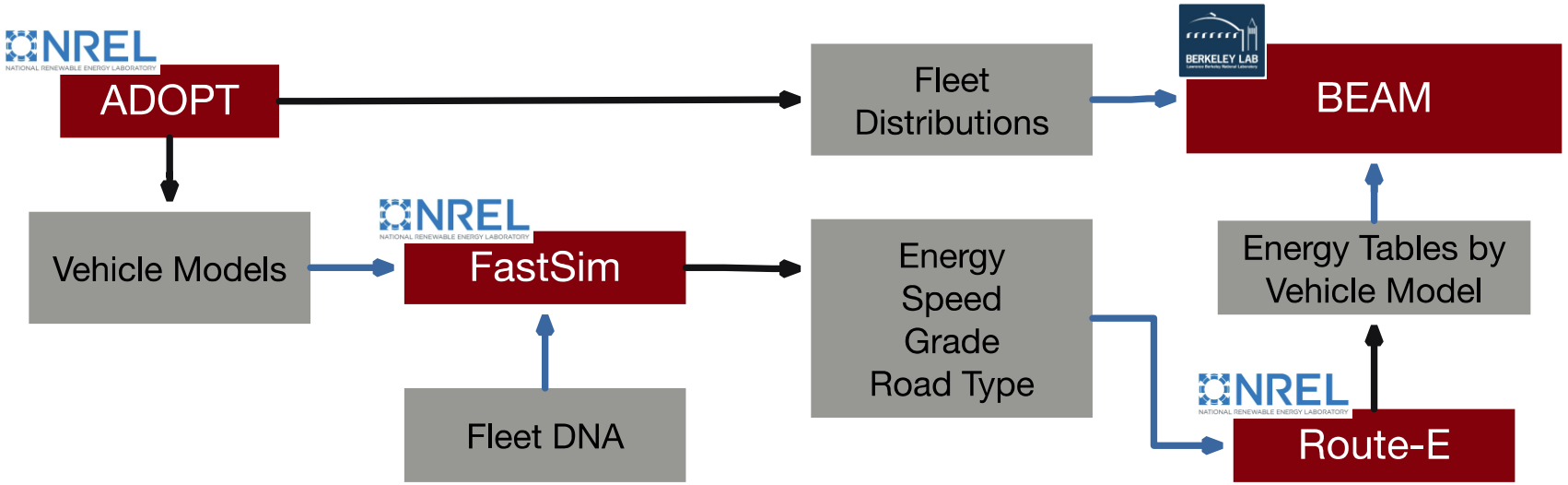
(Household sum of travel times)

Coordinated Adaptive Cruise Control (CACC)

- CACC enables higher throughput on highways and arterials
- CACC model in BEAM based on detailed micro-simulation study by Hoa Et al. (2018)
- We derived polynomial relationship between CACC penetration on road and capacity
- We apply this relation dynamically in the BEAM traffic simulation model
- All high capacity roads (capacity > 2000 veh/h) are now sensitive to CACC enabled vehicles passing through

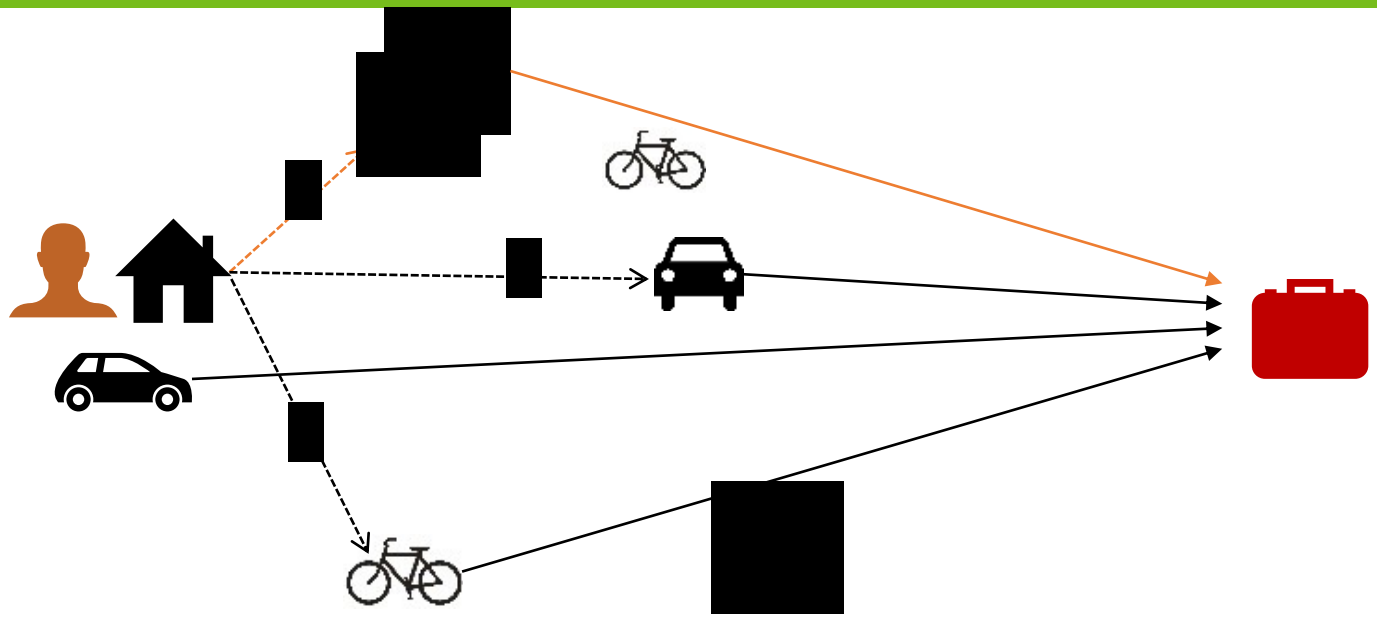


Energy Consumption Modeling in BEAM



- ADOPT used to inform vehicle distribution scenarios as well as powertrain properties for characteristic vehicle models
- FastSim used to simulate vehicle energy consumption over many real-world drive cycles from Fleet DNA
- Route E used to correlate vehicle energy to driving conditions
- BEAM applies energy rates from Route E to each vehicle as it traverses each link

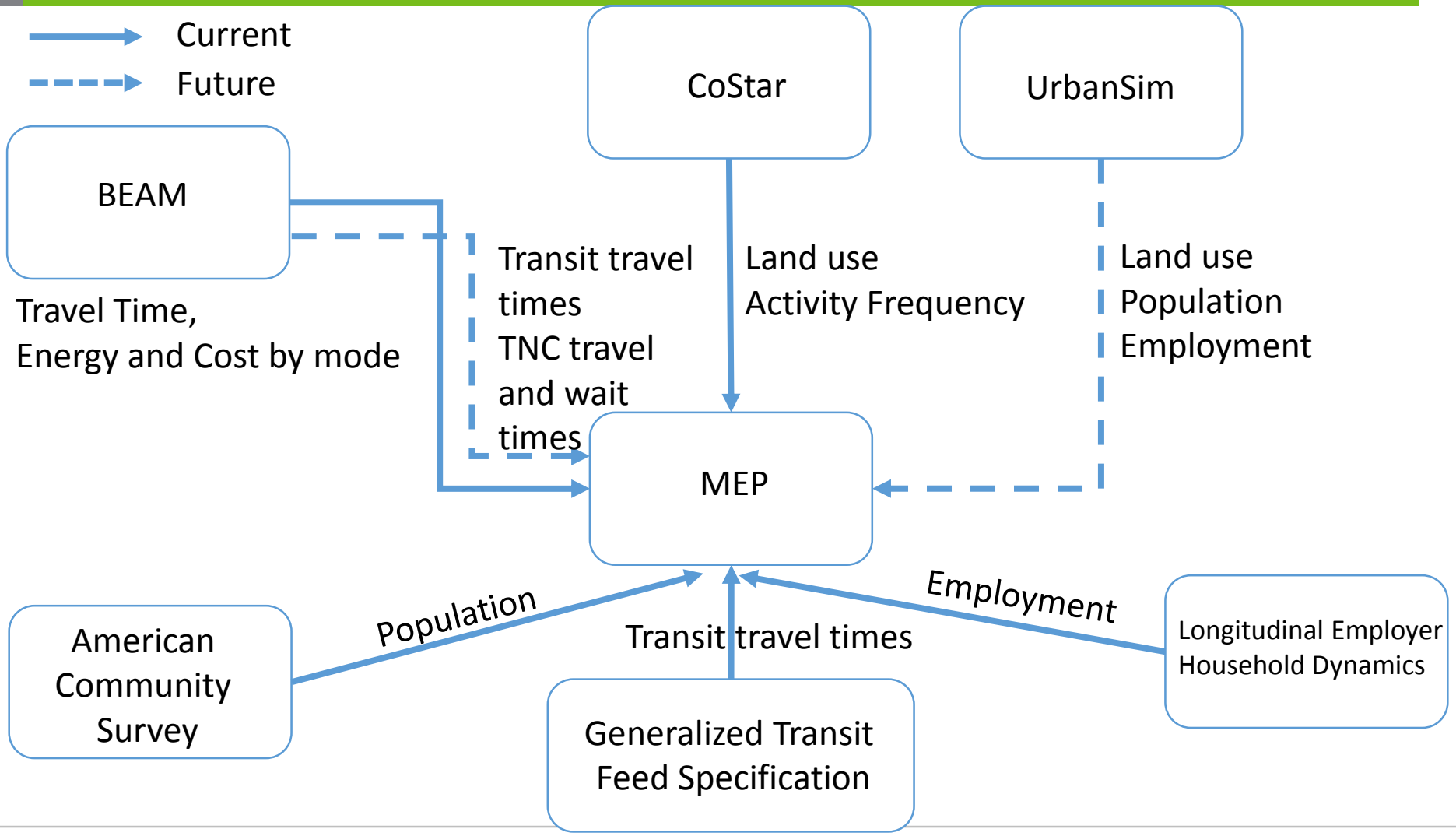
Vehicle Sharing



- Any number of vehicle sharing managers can be added
- Each can own any vehicle type: E-scooter, Bikes, Cars
- Currently only dockless format supported
- Travelers add nearby shared vehicles to their choice set and route accordingly

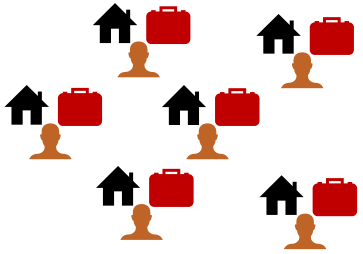
- Work continues to implement general rebalancing algorithm for any vehicle type
- Therefore vehicle sharing not included in simulations / results presented in the following slides

Mobility Energy Productivity (MEP) Integration

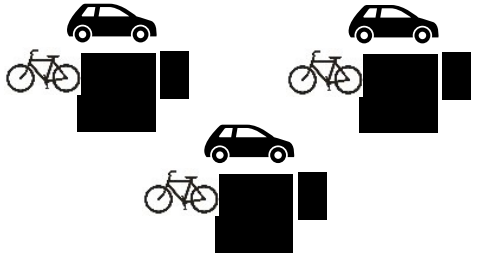


UrbanSim Integration

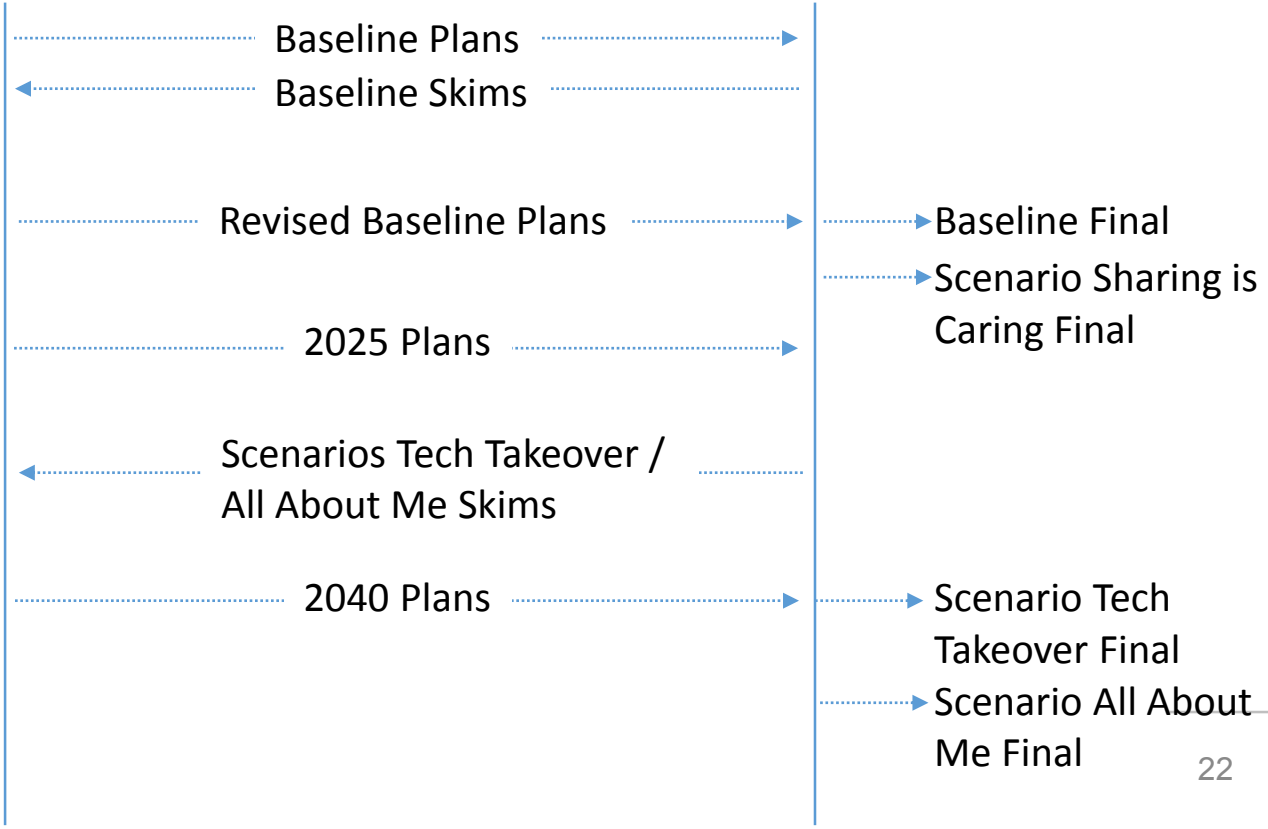
UrbanSim



BEAM

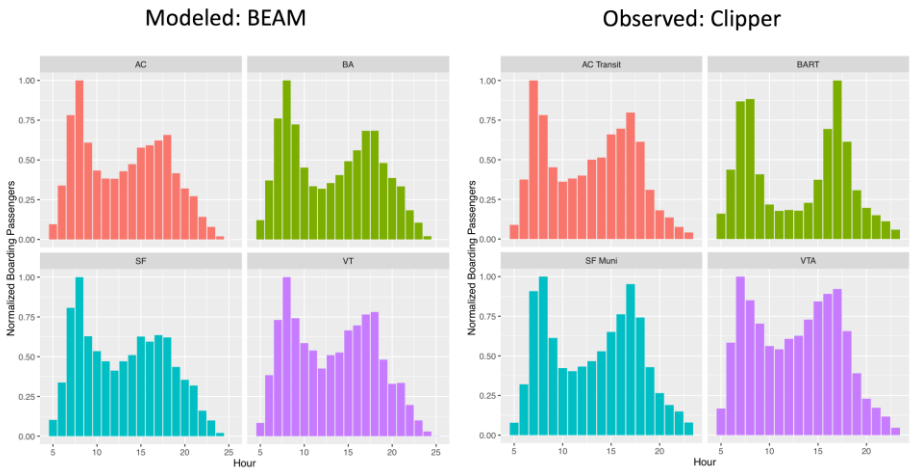


- UrbanSim evolves land-use in metro-areas
- Firms choose where to locate
- Households choose where to live
- Persons choose where to work
- Synthesizes activity chains now used in BEAM

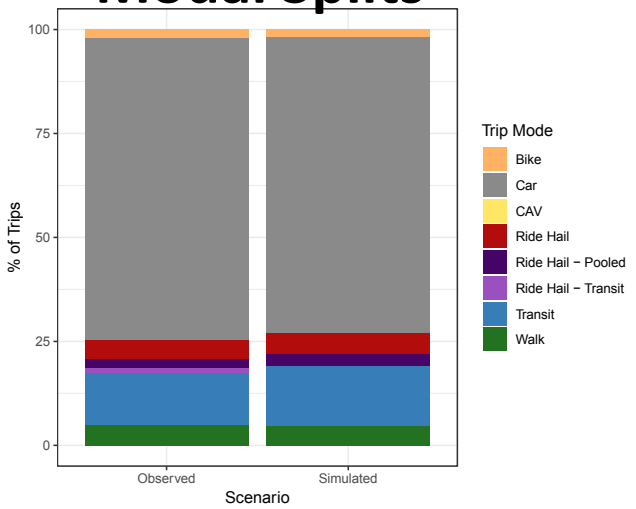


Calibration / Validation

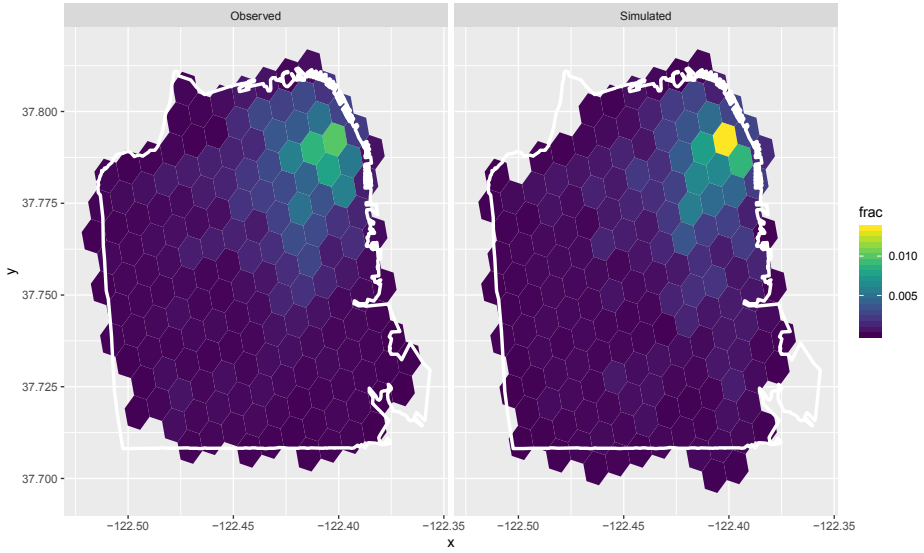
Transit Ridership



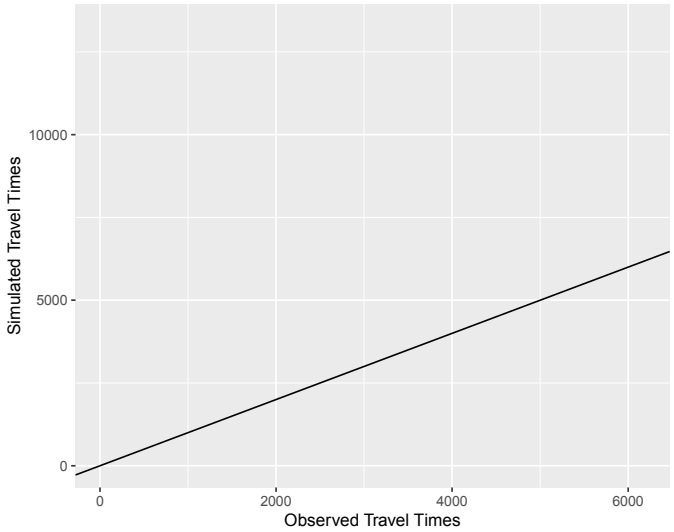
Modal Splits



Ride Hail Spatial Distribution



Travel Times



SMART Common Scenarios

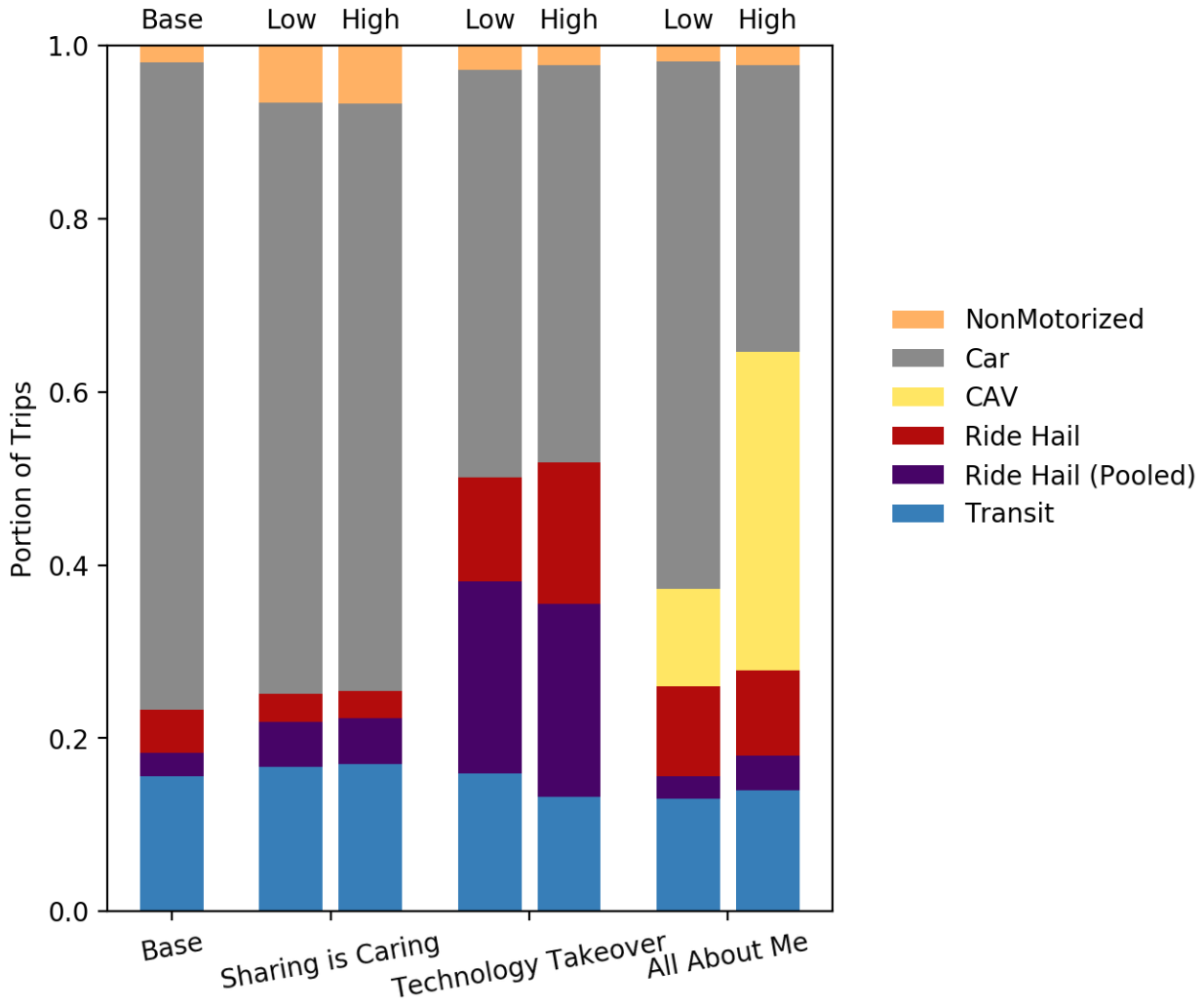
		Sharing is caring	Technology Take-Over	All about Me
Variables	**Baseline**	**High sharing low automation**	**High tech - mobility**	**Low sharing high Automation**
Market Penetration (CAV)	Baseline	Low	High	High
Automation Level	Baseline	Med	High	High
Private Ownership	Baseline	Low	Low	High
Shared Use - commerical	Baseline	High	High	Low
Value of Travel Time (Car Only)	Baseline	High	Low	Low
Propensity non-car modes	Baseline	High	Low	Low
Vehicle Technology (Energy, Cost…)	Baseline	Mid Term Low Tech & Mid Term High Tech	Long Term Low Tech & Long Term High Tech	Long Term Low Tech & Long Term High Tech

Scenarios

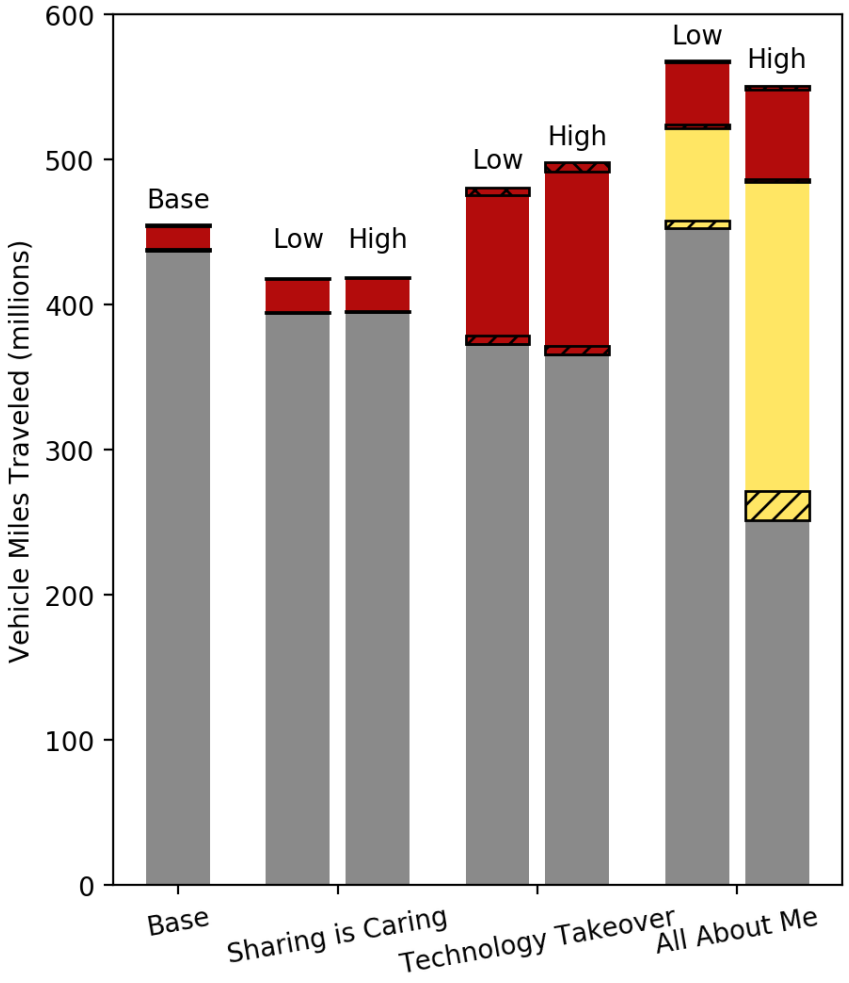
- A - High Sharing Low Automation - New technology (e.g., integrated apps) enables people to significantly increase use of transit, car sharing and multi-modal travel. Low vehicle automation (e.g., CACC) is being introduced mainly on highway system
- B – High Technology Mobility – Technology has reshaped mobility enabling a high usage of ride pooling and multi-modal trips as they are convenient and inexpensive. Private ownership thereby decreases.
- C – Low Share with High Automation – Fully automated vehicles with significant market penetration, especially in households.

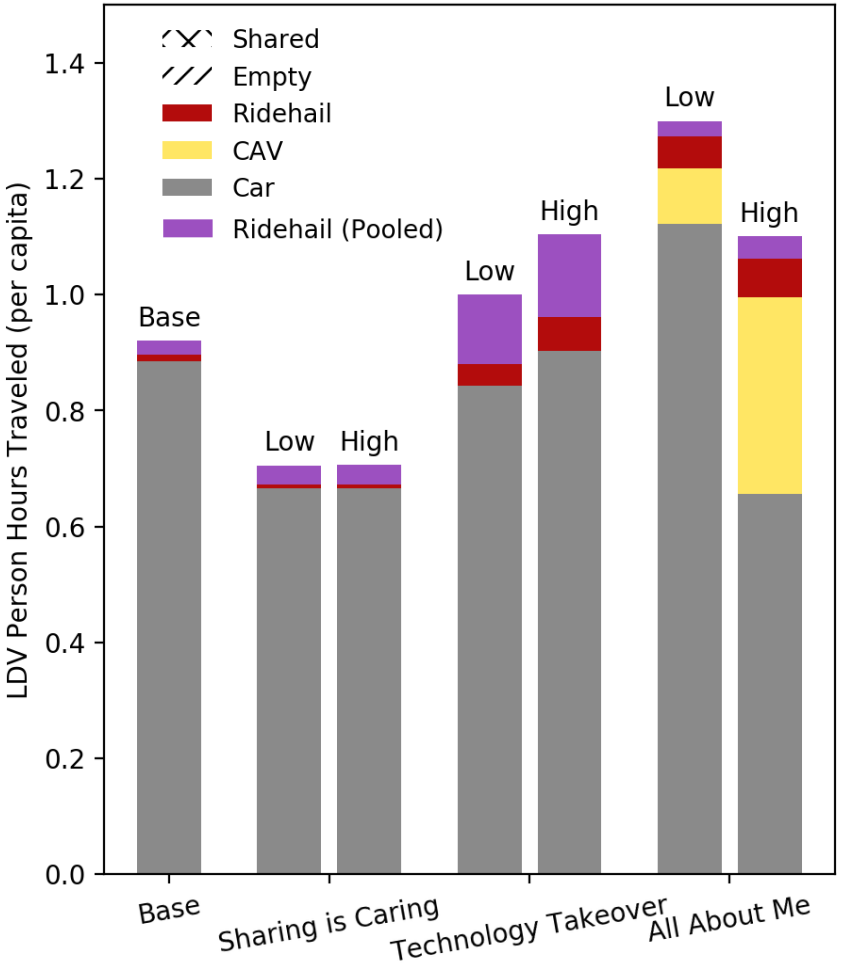
Results: Mode Share

- Car mode share decreases from baseline in all scenarios
- Sharing is caring: increased transit, ride hail, and non-motorized (bike & walk), increased fraction of ride hail is pooled
- Tech takeover: ride hail sees massive increase with a lot of pooling requests (not the same as actual pooled rides)
- All about me: personal CAVs see large penetrations but ride hail also increases over base line.

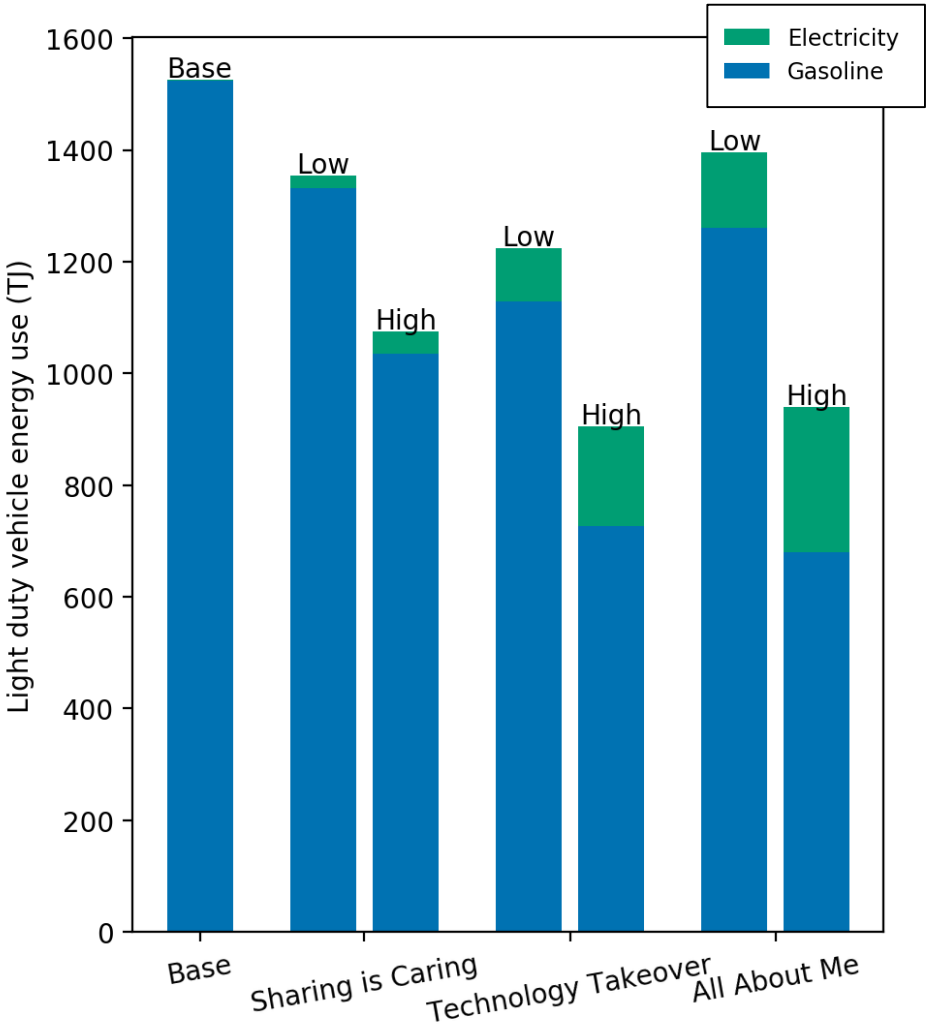


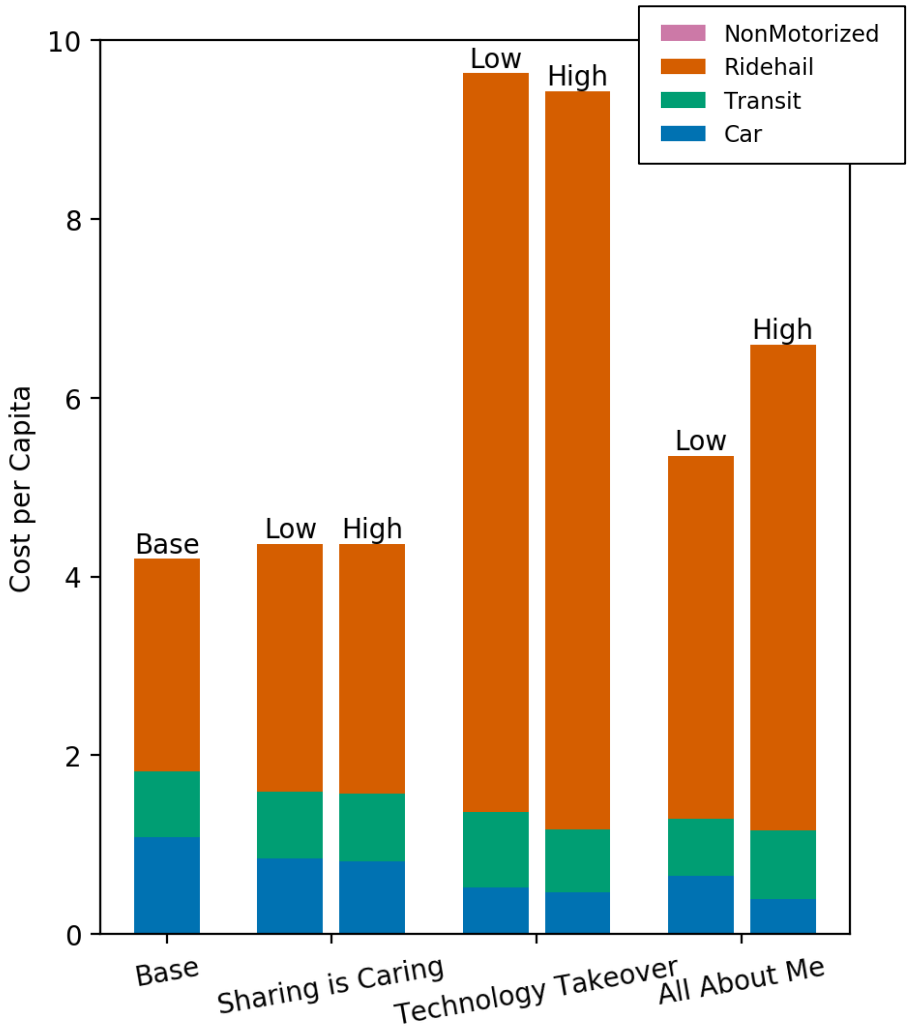
Results: Vehicle Miles/Hours Traveled



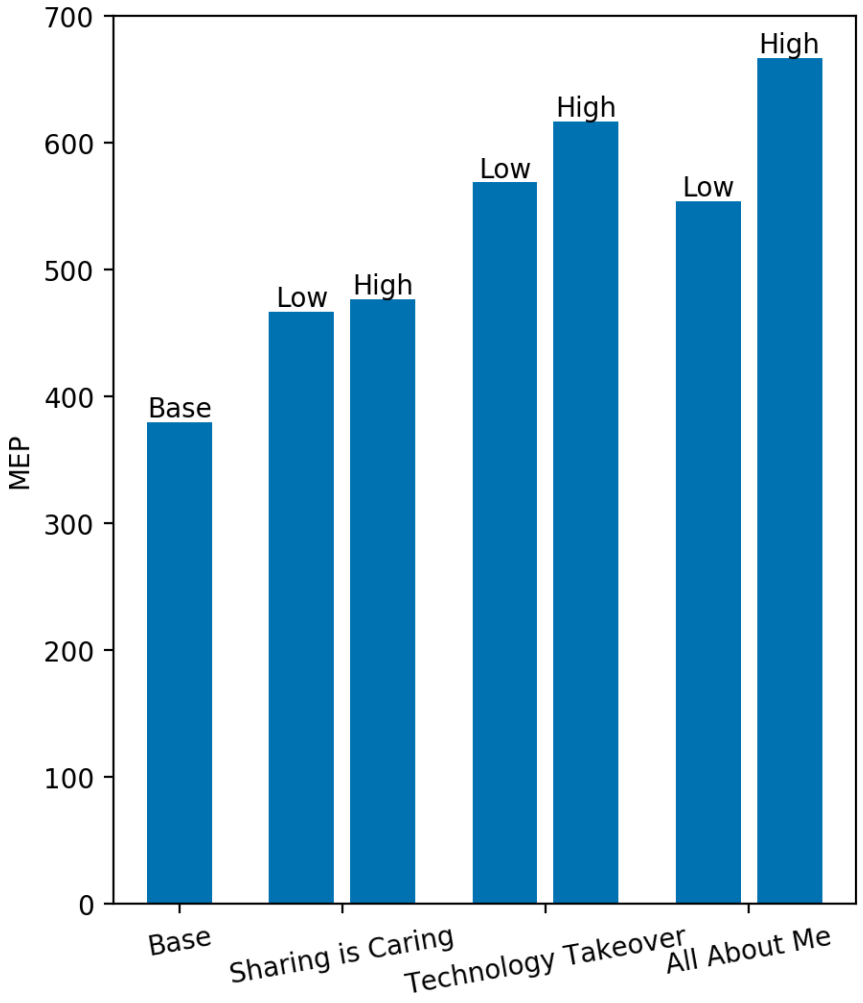


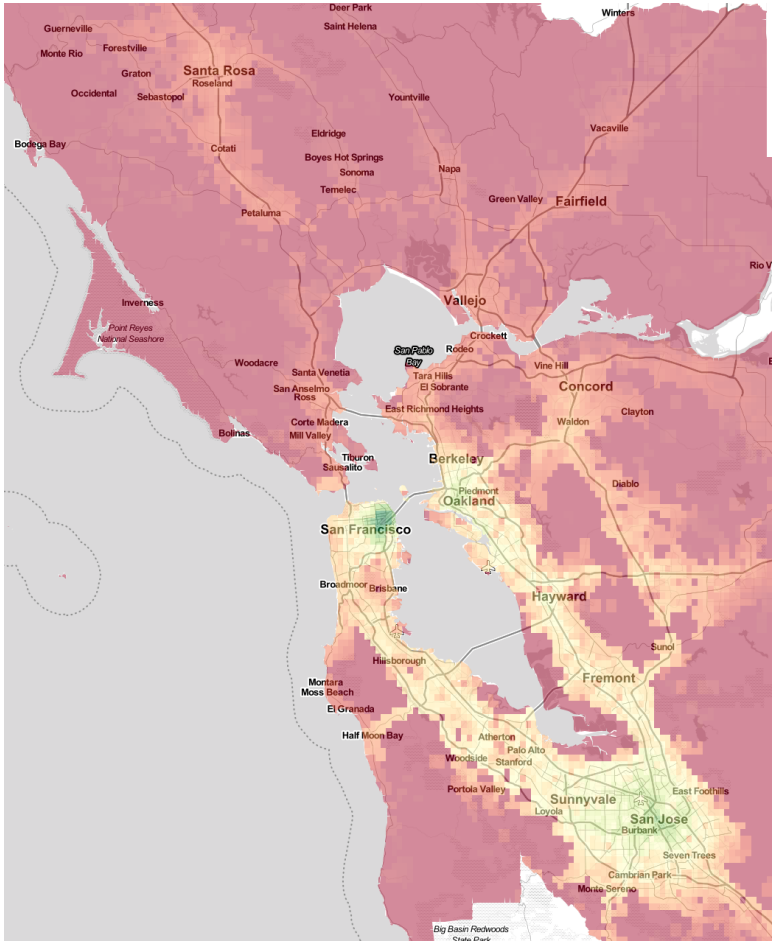
Results: Energy and Cost





Results: Mobility Energy Productivity





Responses to FY18 Reviewers

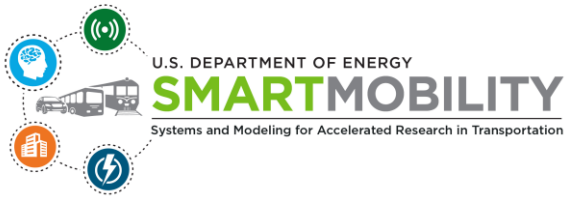
The reviewer commented that the hope would be that, once calibrated and validated, such models could be used to determine the energy impacts of different policies, technologies, or behaviors introduced into implementation.

We agree, this was the intention all along and we have made dramatic strides toward producing results and insights that can inform the impacts of trends, behaviors, and policies.

The reviewer indicated that there are only internal collaborations and no collaborators outside of DOE. The reviewer stated that this is a transportation modeling tool, and asked where the inputs of the transportation planners and providers of transportation services are in order to bring reality to the tool.

Since AMR 2018, we have coordinated with San Francisco County Transportation Authority and received data and assumptions from their modeling and analysis work to use both as input to BEAM and as validation data. We have begun partnerships with other outside entities including other research institutions (UC Davis, UC Irvine, Seoul National University) as well as private industry (Cabify, Marain, others). We have also been approached by government agencies (e.g. California Energy Commission, California Air Resources Board) interested in leveraging BEAM's capabilities. We believe our work is already having an impact beyond SMART Mobility and will continue to do so in the coming years.

Collaborations



- UC Berkeley: Land use modeling, mode choice modeling, ride hail charging infrastructure planning, road capacity vs. CACC relations
- TU Dortmund: Charging behavior modeling
- San Francisco County Transportation Authority: ride hail data and modeling advice
- UC Davis: Mode choice behavioral analysis
- NREL: Vehicle adoption forecasts, reduced form vehicle energy model, charging behavior modeling
- INL: EV Charging Profiles and Ride Hail Control Algorithms
- ANL: Scenario harmonization

Remaining Challenges

- New on-line optimization algorithms have been deployed in BEAM, these present new challenges to scaling the simulation
- Automatically sizing the ride hail fleet instead of manual tuning
- Replanning should always happen jointly for households
- Adding vehicle sharing (e-scooters in particular) to this kind of model has never been done before, challenges in data procurement and validation

Remaining Work

FY19 Remaining Work

- Whole Traveler Integration
  - New estimates of value of travel time for San Francisco Bay Area will be integrated into BEAM
  - New estimates of propensity to adopt new modes will be taken into account
- Vehicle Sharing
  - Based on data, estimate present utilization (and therefore modal preference) and spatial distributions
- Rebalancing
  - New vehicle sharing rebalancing algorithm will be deployed
  - Ride hail rebalancing algorithm will be revised
- UrbanSim Integration
  - Frequency of data passing will be increased through automation and co-simulation

Summary

Across SMART Scenarios:

- Large differences in modal shares
- Large differences in congestion
- But VMT not changing dramatically
- Energy consumption differences largely driven by vehicle technologies
- Congestion puts the primary damper on run-away energy consumption → transit, bike, walk shares are robust to changes

QUESTIONS?

Technical Back-Up Slides

Vehicle Miles Traveled by Automation Level